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BRIEF REPORT

Relationship between Invasive and Echocardiographic Transvalvular Gradients after Transcatheter Aortic Valve Replacement

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ABSTRACT

Introduction: Lower transcatheter aortic valve replacement (TAVR) pressure gradients have been reported after implantation of self-expanding valves compared with balloon-expandable valves; however, there is a paucity of data on the relationship between invasively measured transvalvular pressure gradients and Doppler-derived measurements.

Methods: From September 2013 to September 2018, patients with native aortic valve stenosis who had both intraoperative invasive and postoperative echocardiography transvalvular pressure gradients were included for analysis. We used parametric and nonparametric statistics to compare aortic gradients within and between groups.

Results: Of 171 patients, 152 (88.9%) patients had TAVR with a balloon-expandable valve and 19 (11.1%) with a self-expanding valve. Among all patients, the invasive aortic gradient was 7.8 ± 3.2 mmHg and the Doppler-derived aortic gradient was 11.0 ± 4.5 mmHg ($p < 0.001$). Among those who received a balloon-expandable valve, the invasive aortic gradient was 7.5 ± 3 mmHg and the Doppler aortic gradient was 11.4 ± 4.5 mmHg ($p < 0.001$). In contrast, among patients who received a self-expanding valve, the invasive aortic gradient was 10.3 ± 3.4 mmHg and the Doppler aortic gradient was 8.5 ± 4.6 mmHg ($p = 0.18$).

Conclusions: Balloon-expandable valves were associated with lower invasive measurements versus post-TAVR Doppler gradients, while results were inconclusive regarding self-expanding valves.

Keywords: Balloon-expanding valve; Doppler aortic gradient; Invasive aortic gradient; Self-expanding valve; TAVR

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INTRODUCTION

Transcatheter aortic valve replacement (TAVR) is approved for use in patients with symptomatic severe aortic stenosis irrespective of risk [1–3]. Therefore, prosthetic TAVR valve competency and durability are crucial. Post-procedural transvalvular pressure gradients have been found to be associated with biomechanical stress and deterioration of the prosthetic valve [4]. Previous studies have shown higher post-operative Doppler aortic gradients in balloon-expandable valves versus self-expanding valves [5]; however, there is a paucity of data regarding the correlation of aortic valve gradients obtained invasively and from Doppler-derived measurements. Our aim was to compare invasive versus post-operative Doppler-derived transvalvular pressure gradients after TAVR.

METHODS

The University of Florida Institutional Review Board approved this retrospective study. The study was performed in accordance with the Declaration of Helsinki of 1964 and its later amendments. Informed consent was obtained from all patients for the TAVR procedure. From September 6, 2013, to September 1, 2018, 284 patients with symptomatic severe aortic valve stenosis underwent TAVR at the Malcom Randall Veterans Medical Center in Gainesville, Florida. Among them, 182 patients had both intraoperative invasively measured and post-operative Doppler-derived transvalvular pressure gradient measurements. Eleven patients with valve-in-valve TAVR were excluded; therefore, 171 patients with native aortic valve stenosis were included for final analysis. All TAVR procedures were performed according to current guidelines and standard approaches [6, 7]. Intraoperative invasive transvalvular mean pressure gradient was measured using a Langston dual-lumen pigtail catheter 5–10 min after valve deployment. Postoperative Doppler-derived transvalvular mean pressure gradient was assessed with transthoracic echocardiography within 48 h after TAVR after bedrest restrictions had been lifted. Invasively measured transvalvular pressure gradients and post-operative Doppler-derived measurements were compared among all patients and according to valve type. Student's t test was used for comparison of parametric variables (balloon-expandable valves) and the Wilcoxon rank-sum test was employed for comparison of nonparametric variables (self-expanding valves). To examine the correlation between invasively measured and postoperative Doppler-derived transvalvular measurements, we used Pearson's correlation test. A two-tailed p value ≤ 0.05 was considered statistically significant. Statistics were performed with SPSS software (Version 24, IBM Co., Armonk, NY, USA).

RESULTS

From 171 patients with native aortic valve stenosis who had both invasively measured and postoperative Doppler-derived transvalvular pressure gradient measurements, 152 (88.9%) received a balloon-expandable valve and 19 (11.1%) a self-expanding valve. Mean ± SD age was 76.9 ± 9.1 years, and the majority of patients were men (n = 167, 97.7%). The mean ± SD pre-procedure mean aortic gradient was 41.5 ± 12.4 mmHg. The overall mean ± SD invasive mean aortic gradient was 7.8 ± 3.2 mmHg, and the Doppler-derived

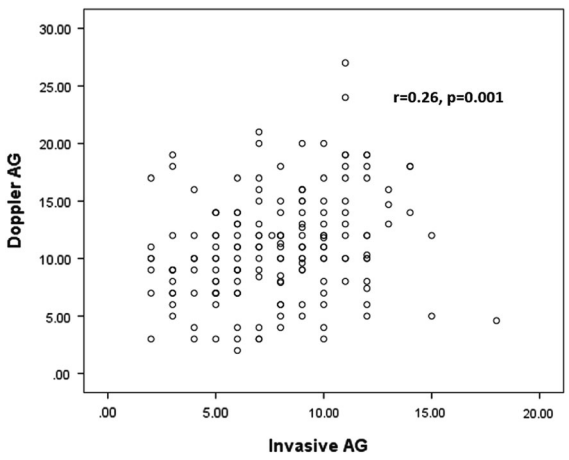

Fig. 1 Correlation between intraoperative invasive and post-operative Doppler aortic gradients (AG)

mean aortic gradient was 11.0 ± 4.5 mmHg ($p < 0.001$) (Fig. 1).

Mean area-derived and perimeter-derived diameters were comparable between balloon-expandable and self-expanding valves (Table 1). Among patients who underwent TAVR with a balloon-expandable valve, the invasive mean aortic gradient was 7.5 ± 3 mmHg and the Doppler-derived mean aortic gradient was 11.4 ± 4.5 mmHg ($p < 0.001$). In contrast, in patients who received a self-expanding valve, the invasive mean aortic gradient was 10.3 ± 3.4 mmHg and Doppler-derived mean aortic gradient was 8.5 ± 4.6 mmHg ($p = 0.18$).

One hundred and forty-six patients had TAVR with a new-generation Sapien 3 valve. The invasive mean aortic gradient was 7.4 ± 3 mmHg, and the Doppler-derived mean aortic gradient was 11.5 ± 4.5 mmHg and ($p < 0.001$). Among 14 patients who underwent TAVR with an Evolut R or Evolut Pro valve, the invasive mean aortic gradient was 10.1 ± 3.7 mmHg, and the Doppler-derived mean aortic gradient was 7.7 ± 4.5 mmHg ($p = 0.14$).

DISCUSSION

This study reports on bioprosthetic TAVR valve hemodynamics. We document the following findings: (1) Balloon-expandable valves were associated with lower invasively measured transvalvular pressure gradients versus post-TAVR Doppler-derived gradients. (2) Among self-expanding valves, invasive gradients were similar versus post-TAVR Doppler-derived gradients.

Now that the United States Food and Drug Administration has approved TAVR for low

Table 1 Annulus diameter, invasive and Doppler aortic gradients according to valve type

Valve	Number	Valve size mm (*n*)	Area-derived diameter	Perimeter-derived diameter	Invasive mean gradient	Echo mean gradient	*p* value
Total	171		25.2 ± 1.8	25.7 ± 1.9	7.8 ± 3.2	11.0 ± 4.5	< 0.001
Balloon-expandable	152	23 (14)	25.3 ± 1.9	25.8 ± 1.9	7.5 ± 3	11.4 ± 4.5	< 0.001
		26 (82)					
		29 (56)					
Sapien 3	146	23 (14)	25.3 ± 1.9	25.8 ± 1.9	7.4 ± 3	11.5 ± 4.5	< 0.001
		26 (78)					
		29 (54)					
Self-expanding	19	26 (1)	24.8 ± 1.8	25.5 ± 1.8	10.3 ± 3.4	8.5 ± 4.6	0.18
		29 (10)					
		31 (4)					
		34 (4)					
Evolut R/Pro	14	26 (1)	24.4 ± 1.8	25.1 ± 1.9	10.1 ± 3.7	7.7 ± 4.5	0.14
		29 (9)					
		34 (4)					
p value for balloon vs. self-expanding			0.25	0.47	0.002	0.016	

surgical risk patients with potentially younger age, bioprosthetic valve durability and proper function are vital for freedom from symptoms and reoperation. Post-TAVR transvalvular pressure gradients and valve hemodynamics have important roles in valve durability and patient outcomes [8]. Higher aortic gradients after implantation are associated with more biomechanical stress and valve deterioration [9].

The finding that self-expanding valves were associated with lower Doppler-derived aortic valve gradients than balloon-expandable valves confirms previous studies [5, 10, 11]. Lower transvalvular gradients in self-expanding versus balloon-expandable valves after TAVR may be related to supra-annular function of the self-expanding valves [12]. Regarding invasive measurements, there was a suggestion that balloon-expandable valves were associated with lower trans-valvular gradients than self-expanding valves; however, due to limited numbers, this needs to be interpreted with extreme caution.

Overestimation of transvalvular gradients from Doppler-derived measurements versus invasive measurements is well described to occur in native aortic stenosis and after TAVR and is attributed to the pressure recovery phenomenon [13–17]. A schematic diagram of pressure recovery between invasive and Doppler-derived measurements is illustrated in Fig. 2 [18]. Invasive measurements are able to account for pressure recovery by measuring the aortic pressure at the point where turbulent flow converges to laminar flow. It is possible that invasive pressure acquisition might be different between valve types. For example, when a dual-lumen pigtail catheter is used within a self-expanding valve, the aortic pressure might be measured within a region of turbulent flow and thus not able to fully account for pressure recovery and overestimate the transvalvular pressure gradient. Accordingly, use of two single-lumen pigtail catheters might be preferential for assessment of self-expanding valve hemodynamics. This could also help to explain the possible difference in invasive pressures between valve types.

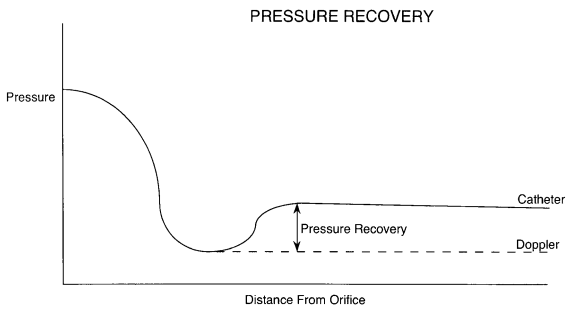

Fig. 2 Schematic diagram of pressure recovery between invasive and echocardiography techniques. Reprinted with permission from [18]

Other study limitations include: (1) This was a single-center retrospective study with limited sample size, especially for self-expanding valves, which precluded direct comparison between valve types. (2) High-fidelity micromanometer catheter tips (i.e., Millar) were not used; however, our technique for obtaining pressures was meticulous and systematic. (3) Increases in stroke volume, which are known to increase Doppler gradients, were not directly accounted for (i.e., post-procedural anemia) and were assumed to be similar. This was a potential issue since transthoracic echocardiography was performed within 48 h after TAVR.

CONCLUSIONS

Balloon-expandable valves were associated with lower invasive gradients versus post-TAVR Doppler-derived gradients. Further studies with larger patient populations are warranted to better understand bioprosthetic TAVR valves hemodynamics.

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Compliance with Ethics Guidelines. The University of Florida Institutional Review Board approved this retrospective study. The study was performed in accordance with the Declaration of Helsinki of 1964 and its later amendments. Informed consent was obtained from all patients for being included in the study.

Data Availability. The datasets generated during and/or analyzed during the current study are available, in anonymized form to protect patient privacy, from the corresponding author on reasonable request.

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